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Authors note

This work contains information already published in other studies and also new information, aiming to disseminate data about the cowpea crop in Brazil in English language.

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Presentation

Cowpea, a traditional crop in the Northeastern Brazil, has been expanding to other regions of the country, specially to Midwest, given its wide adaptability to tropical conditions and low production costs, as well as the intense work of breeding that has been applied to the crop in the last 20 years. For long time cultivated only by family farmers, the crop launched to bigger areas due to the efficient breeding program performed at Embrapa, which covered the obtention of cultivars with modern architecture and suitable for mechanical harvesting. It is important to highlight the recent incorporation of cowpea in production arrangements of soybean, rice and corn, mainly during second crop period, causing a rapid expansion of its farming. Factors like the high quality of grains, nutritional value and regularity of supply in terms of quantity and standardization of the product have called the attention of traders, agribusiness people and distributors, contributing to the opening of important markets, including abroad.

This work collabotares effectively to the consolidation of cowpea crops in Brazil, considering their rising incorporation to production systems in line with advanced crop techniques, the remarkable expansion of the crop and the new possibilities in the market.

Hoston Tomás Santos do Nascimento
Embrapa Mid-North's Director-General

Summary

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Introduction

About 50 years ago cowpea was reported as a relatively minor tropical legume. However, in the last years, it has been emerging as one of the most important food legume of the 21st century (SINGH, 2010). Brazil is not out of this panorama. Brazilian agriculture is undergoing major technological changes and, in addition, globalization in agribusiness has caused impacts on the production chain of several crops, particularly those heavily dependent on the use of a large volume of agricultural inputs, mainly fertilizers and pesticides. Such crops have had a higher production cost each year. On the other hand, this situation has brought new opportunities. Business farmers have sought new alternatives for their production arrangements. In this context cowpea constitutes one of the best options.

Due to this, in the last years cowpea cultivation is expanding to the cerrado regions, in the North, Northeast and Midwest of Brazil, where it is incorporated to the cropping arrangements as off-season crop following the harvests of soybean, rice and, in some cases, after corn, although it may be the main crop in some locations. In the cerrado region, especially when grown as off-season crop, cowpea has a very competitive cost, which has contributed to increase the interest of farmers. The availability of a standardized high-quality product, with sufficient quantity and regularity, has aroused the interest of agribusiness players from different regions, contributing to open new markets for this crop.

The National Agricultural Research System (SNPA) has been genetically improving cowpea by taking into account the interests of family and business farmers, with a focus on producers, traders, the agro-industrial sector, distributors, consumers and, recently, exporters.

This paper discusses production data, socioeconomic information, genetic improvement results and provides comments on cowpea crop in Brazil.

Background

Possibly because of the large genetic variability found in this species (*Vigna unguiculata* (L.) Walp.) and in genetically related wild species, classifying the domesticated species has proved to be rather difficult. Therefore, cowpea was initially classified as belonging to the genera *Phaseolus* and *Dolichos*, before being classified as belonging to the genus *Vigna*, established by Savi in 1894 (Phillips, 1951, quoted by SELLSCHOP, 1962). Similarly, several classifications were made at species level before reaching the current classification. Thus, the scientifically accepted classification states that cowpea is a Dicotyledon plant, of the order Fabales, Fabaceae family, Faboideae subfamily, Phaseoleae tribe, Phaseolineae subtribe, genus *Vigna*, subgenus Vigna, section Catyang, species *Vigna unguiculata* (L.) Walp. and subspecies *unguiculata* (MARÉCHAL et al., 1978; PADULOSI; NG, 1997; SMARTT, 1990; VERDCOURT, 1970).

Cowpea is a crop with an African origin, which was introduced in Brazil in the second half of the sixteenth century by Portuguese settlers in the State of Bahia (FREIRE FILHO, 1988). Gandavo (2001) says that, back in 1568, the existence of many varieties of beans had already been reported in Brazil. Souza (1974) refers to the fact that in 1587 a wide variety of beans and broad beans were cropped in Bahia. Although one can not specify which beans were cropped at that time, there is very strong evidence that cowpea was one of such crops. According to Barracloug (1995), the trade with West Africa, from Guinea to Angola, became intense after Bahia was established as the administrative capital of Brazil in 1549. From Bahia, cowpea spread across the country. In Piauí, a state colonized from the countryside to the coast and where certainly the communication and trade with the countryside were more difficult than with the coast, the bean crops are reported as taking place back in 1697 (DIAS, 2008). This information suggests that bean crops had been intensely disseminated, especially in the Northeast region and from the Northeast region to the whole country.

Popular names

It is relevant to explain that cowpea has several popular names, which may sometimes confuse people. Thus, in order to clarify any potential mistake, some of the popular names in Brazil are described as following: *feijão-macássar* and *feijão-de-corda*, in the Northeast region; *feijão-de-praia*, *feijão-da-colônia* and *feijão-de-estrada*, in the North; *feijão-miúdo*, in the South (FREIRE FILHO et al., 1983). In the North there is a very small, cream-colored variety of cowpea, very popular in the local cuisine, which is called *manteiguinha* (cream beans). Cowpea is also called *feijão-gurutuba* and *feijão-catador* in some regions of the State of Bahia and in northern portion of Minas Gerais. Besides such names, there is a type of grain with a white coat and a large black halo, which is called *feijão-fradinho* (black-eyed beans) in the states of Alagoas, Sergipe, Bahia and Rio de Janeiro. *Feijão-fradinho* is the most used for the preparation of acarajé, similar to akara balls. It is a typical food from Bahia, very appreciated throughout Brazil. Other popular names used in other countries are presented in Table 1.

Table 1. Scientific and popular names of cowpea in different languages and countries.

Scientific name	Common names				
	Portuguese	**Spanish**	**English**	**French**	**Hindi**
Vigna unguiculata (L.) Walp. ssp. *unguiculata* Verdc.	Brazil [1]	Mexico[2]	United States of America [4,6,8]	France[8]	India[5]
	Feijão-caupi;	Xpelon (em Maia)	Cowpea;	Haricot á ceil noir	Lobia e Chaura (em Hindu);
	Feijão-macassa;	Guatemala[2]	Southernpea;	Haricot á l'ceil	Chola e Chorap (em Guajarati);
	Feijão-macássar;	Ixpelon; Perome; Cachito; Riata	Blackeyepea;	Cornille; Pois du;	Chavalya (em Marathi);
	Feijão-de-corda;	El Salvador[2]	Blackeyed peas;	Brésil; Kundew;	Alasandulu (em Tegulu);
	Feijão-de-praia;	Frijol da costa	Blackeyed beans;	Senegal[3,7]	Alasande (em Kannada);
	Feijão-miúdo	Costa Rica[2]	Field peas	Niébé, Seub, Niao	Karamani (em Tamil)
	Portugal	Rabiza	Guyana [2]	Haiti[2]	
	Feijão-frade;	Panamá[2]	Cowpea	Pois inconnu	
	Feijão-fradinho	Frijol	Suriname[2]		
	Angola	Ecuador[2]	Cowpea		
	Feijão-macúndi;	Tumbe; Chileno	Jamaica[2]		
	Maconde	Colombia[2]	Cowpea		
	Mozambique [9]	Frijol caupi	Trinidad and Tobago[2]		
	Nhemba	Venezuela[2,8]	Bodie beans		
	Namurua	Frijol; Caupi	Nigeria[7,11]		
	Ecúte	Dominican Republic[2,8]	Wake		
		Anconi; frijol	Beans		
		Puerto Rico[8]	Sudan[7]		
		Frijol	Luba hilu		
		Peru[3]	West Africa		
		Frijol castilha; Caupi;	Wake [6,10]; Niébé [6,11,12];		
		Chileno cuarenta; Chiclyo (Selva)	Cowpea [6]; Ewa [6]		
		Ojo negro; Boca negra	East Africa[11]		
		Bolivia[3]	Kunde		
		Frijol camba			
		Paraguay[3]			
		Porotro; Cumaná			
		Cuba[10]			
		Frijol carita			

[1]Freire Filho et al. (1983a; 2005a). [2]Woolley (1980). [3]Sène (1968). [4]Fery (2002). [5]Nene (2006). [6]Timko et al. (2007). [7]Timko and Singh (2008). [8]PERÚ (2010). [9]Marques Cachifo Dembo Donça, agronomic engineer, personal communication on September 20th, 2011. [10]Moacir Antonio Tomazetti, business farmer, personal communication on June 20th, 2010. [11]Singh (2010). [12]Francophone countries.

Cropping and socioeconomic importance

In Brazil, several species of beans are cropped; however, for the purposes of a technical regulation, only the common beans, species *Phaseolus vulgaris* (L.), and cowpea species *Vigna unguiculata* (L.) Walp. are considered to be beans by the Ministry of Agriculture, Livestock and Food Supply – MAPA (BRAZIL, 2008). These two species have the highest social and economic relevance in the country. Cowpea crops concentrate in the North and Northeast, but they are spreading to the Midwest, especially to the State of Mato Grosso. In the North and Northeast, cowpea is cultivated by small, medium family and business farmers; in the Midwest, only by business farmers (Figure 1).

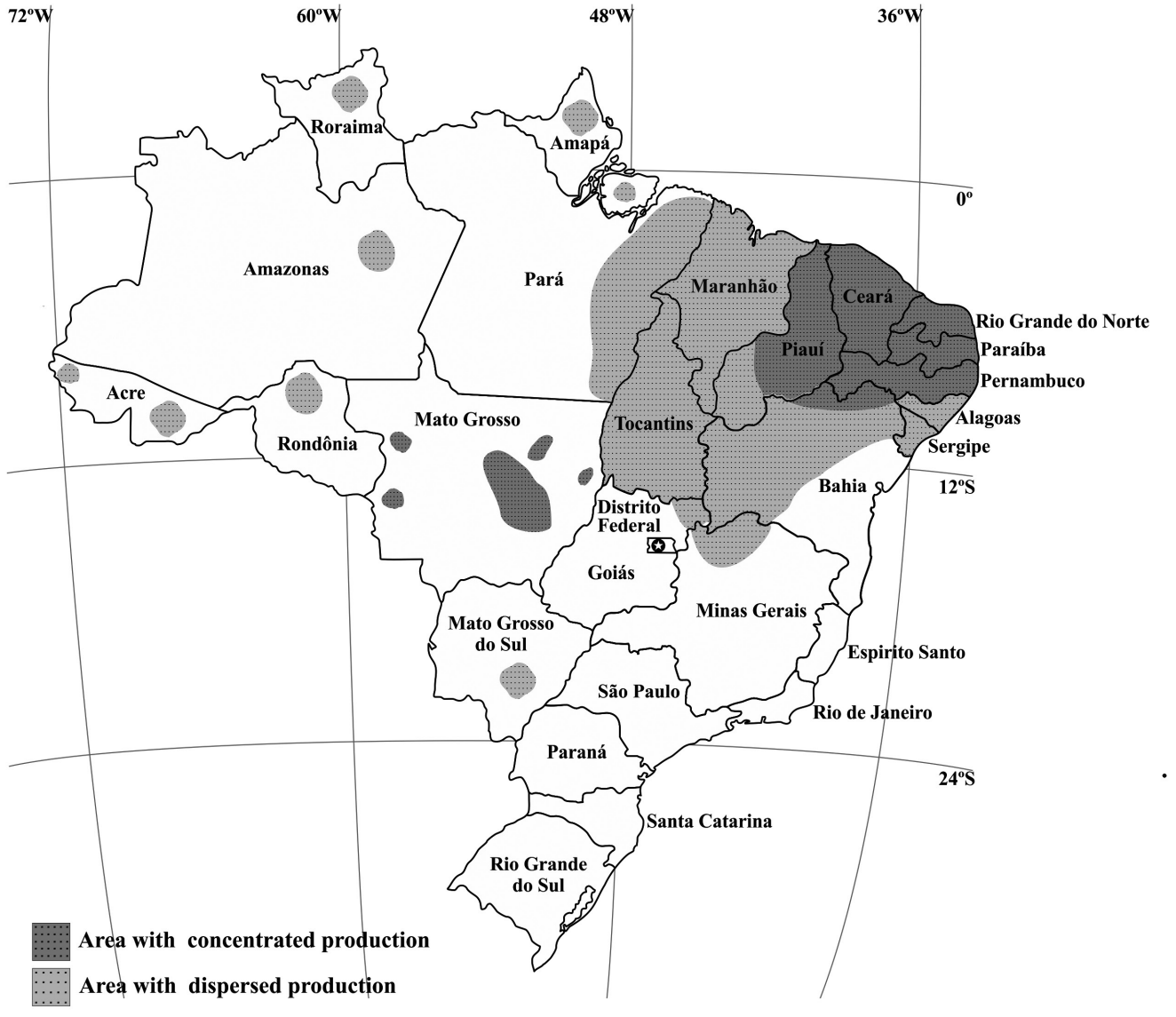

Figure 1. Overall distribution of cowpea cropping regions in Brazil.

Traditionally, cropping in the Northeast has been concentrated in semi-arid areas, where other annual crops will not grow satisfactorily due to erratic rainfall rates and high temperatures. In the Northeast and North regions, cowpea is cropped by family and business farmers, especially the first, who still employ traditional methods. In the Midwest, where cowpea has been cropped on a large scale, production comes mainly from medium and large entrepreneurs, employing highly technical cropping methods.

This work estimated the percentage of cowpea production in relation to bean total production in the country, including the period from 2005 to 2009 (Table 2). Data demonstrate that, in this period, on average, cowpea cropping areas accounted for 33.08% of the total bean cropping areas (Common bean+ cowpea) in the North, 60.80% in the Northeast and 18.05% in the Midwest. In the same period, the production of cowpea corresponded to 37.64% in the North, 45.67% in the Northeast and 9.12% in the Midwest. The cowpea yield represented 113% of total bean yield in the north region (common bean + cowpea), 75.3% in the Northeast, 53.26% in the Midwest. Considering the total bean production average in the country over the period from 2005 to 2009, cowpea accounted for 37.53% of the harvested area, namely 15.48% of total production, with an yield approaching to 42.20% of national yield. Particularly in the Northeast, cropping parameters are not satisfactory; however, this represents an opportunity because opening new areas is not required for increasing harvest; investing in technology is enough to increase yield and, consequently, production.

Cowpea is of great relevance, both as food and to generate employment and income. It has a high content of protein, minerals and fiber (FROTA et al., 2008; SINGH, 2007) and constitutes a basic food component for the rural and urban populations in the North and Northeast regions; moreover, consumption is currently expanding more in the Midwest and Southeast regions of Brazil. Considering the average in the period from 2005 to 2009, a 1,391,386 ha area was harvested, whilst cowpea production reached as much as 513,619 t. Assuming that each hectare generates as many as 0.8 jobs/year, and assuming a per capita consumption of 18,21 kg/individual/year (FEIJÃO..., 2009) and the minimum price of US$ 45.71 per 60-kilo (HETZEL, 2009), it suggests that cowpea crops generated an average of 1,113,109 jobs per year, provided food supply to 28,205,327 million individuals and generated an annual production value of US$ 391,328,761.7 (Table 3).

Table 2. Estimates of the average of cultivated area, production and yield of cowpea in Brazil, from 2005 to 2009.

Region/state	Season[(1)]	Cultivated area (ha)		Production (t)		Yield (kg/ha)	
		Average of period	Average (%)	Average of period	Average (%)	Average of period	Average (%)
North							
Rondônia	1st season	1,904	0.05	1,230	0.04	646.16	73.84
Acre	2nd season	1,076	0.03	545	0.02	506.83	57.92
Amazonas	2nd season	3,751	0.10	3,580	0.11	954.42	109.08
Roraima	2nd season	1,387	0.04	925	0.03	666.76	76.20
Pará [(2)]	2nd season	39,348	1.06	33,425	1.01	849.46	97.08
Amapá	2nd season	1,422	0.04	1,029	0.03	723.97	82.74
Tocantins	1st season	4,480	0.11	2,837	0.09	678.75	77.57
	2nd season	1,497	0.04	1,749	0.05	1,168.35	133.52
Cowpea		**54,565**	**1.47**	**45,321**	**1.37**	**830.58**	**94.92**
Common bean + cowpea		**164,985**	**4.45**	**121,273**	**3.65**	**735.06**	**84.00**
Cowpea(%)		**33.07**		**37.64**		**113.00**	
Northeast							
Maranhão	1st season	37,206	1.00	14,516	0.44	377.90	43.19
	2nd season	48,398	1.31	24,570	0.74	507.67	58.02
Piauí	1st season	221,787	5.98	51,225	1.54	230.96	26.40
	2nd season	7,621	0.21	4,865	0.15	638.43	72.96
Ceará [(2)]	1st season	52,283	14.10	158,910	4.79	303.95	34.74
	2nd season	13,223	0.36	11,997	0.36	907.27	103.69
R. G. do Norte	1st season	57,370	1.55	24,992	0.75	414.34	47.35
	2nd season	1,243	0.03	908,400	0.03	730.69	83.51
Paraíba[(2)]	2nd season	109,152	2.94	36,496	1.10	334.36	38.21
Pernambuco[(2)]	1st season	141,863	3.83	39,893	1.20	281.21	32.14
	2nd season	27,618	0.74	14,359	0.43	519.92	59.42
Alagoas	2nd season	9,170	0.25	4,458	0.13	486.16	55.56
Sergipe	2nd season	2,725	0.07	1,494	0.05	548.18	62.65
Bahia[(2)]	1st season	89,445	2.41	37,682	1.14	421.29	48,15
Cowpea		**1,289,647**	**34.79**	**426,367**	**12.85**	**329.55**	**37.67**
Common bean + cowpea		**2,121,816**	**57.24**	**928,567**	**27.98**	**437.63**	**50.01**
Cowpea (%)		**60.80**		**45.67**		**75.30**	
Midwest							
Mato Grosso do Sul	2nd season	924	0.02	1,070	0,03	1,158.90	132.45
Mato Grosso[(3)]	2nd season	46,250	1.25	40,861	1,23	883.48	100.97
Cowpea		**47,174**	**1.27**	**41,931**	**1,26**	**960.38**	**109.78**
Common bean + cowpea		**233,605**	**6.30**	**421,241**	**12,69**	**1,803.22**	**206.08**
Cowpea (%)		**18.04**		**9.12**		**53.26**	
Total							
North, Northeast and Midwest							
Cowpea		**1,391,386**	**37.53**	**513,619**	**15.48**	**369.14**	**42.19**
Common bean + cowpea		**2,520,406**	**67.98**	**1,471,081**	**44.33**	**583.67**	**66.70**
Cowpea (%)		**55.20**		**34.91**		**63.25**	
Total							
Brazil							
Cowpea		**1,391,386**	**37,53**	**513,619**	**15.47**	**369.14**	**42.19**
Common bean + cowpea		**3,707,361**	**100**	**3,318,614**	**100**	**874.83**	**100**
Cowpea (%)		**37.53**		**15.48**		**42.19**	

[(1)] Considering the cropping of common bean and cowpea, 1st season corresponding water season, 2nd season corresponding dry season and 3rd season corresponding irrigated or winter season (only for common bean). [(2)]Estimates based on Sistematic Survey of Agricultural Production (LSPA) (LEVANTAMENTO... 2005, 2006, 2007, 2008, 2009). [(3)] Data provided by Seeds Tomazetti on May 20th, 2010.

Table 3. Socioeconomic parameters of cowpea crop, 2005-2009 average.

Parameter	Unity	2005-2009
Harvested area [(1)]	ha	1,391,386
Yield [(1)]	t	513,619
Number of jobs generated	0.80 job/ha/year	1,113,109
Potential food supply	18.21 kg/person/year[(2)]	28,205,327
Value of production (US$)[(3)]	47.71/60 kg[(4)]	391,328,761.7

[(1)] Cowpea data estimated from data collected by IBGE (LEVANTAMENTO..., 2005, 2006, 2007, 2008, 2009). [(2)] Hetzel (2009). [(3)] Exchange rate 1.0 US$ = 1.75 R$. [(4)] Governamental minimum price of a 60-kg bag (Hetzel, 2009).

Types of commercial grain

The characterization and classification of cowpea grain by color, coat texture, size, shape and the type of hilum ring and halo is necessary for many years. This necessity today is even greater because cropping is undergoing a market world wide expansion. Through Normative Ruling n° 12, of March 28, 2008, the Ministry of Agriculture, Livestock and Food Supply (MAPA) enacted the new Bean Technical Regulation Act (BRAZIL, 2008), establishing a series of changes in relation to the previous Act (BRAZIL, 2002) and through Act n° 4, of August 19, 2010, established the descriptors for cowpea cultivars (BRAZIL 2010).

With regard to the cowpea, and in addition to the official classification, which reaches only the Class, Freire Filho et al. (2000, 2005) subdivide White and Color grain classes in subclasses, and Freire Filho et al. (2011) include new classes and introduce some changes in the definition of subclasses. Classes and subclasses are specified below:

a) White Class: at least 90% of the grains have a white tegument:

a.1. Smooth White Subclass: cultivars with white, smooth, haloless tegument grains, with a wide range of sizes and shapes (Figure 2).

a.2. Rough White Subclass: cultivars with white, rugous, reniform haloless tegument grains, with little variation in size and relatively large grain (Figure 3).

a.3. Black-eyed pea Subclass: cultivars with white rugous tegument grain and a black halo with sharp edges (Figure 4).

a.4. Brown-eyed Subclass: cultivars with white smooth tegument grain and a brown halo with sharp edges (Figure 5).

a.5. Red-eyed Subclass: cultivars with white smooth or rugous tegument grain and a red halo with sharp edges (Figure 6).

b) Black Class: at least 90% of the grains have a black tegument, either bright (Figure 7) or opaque (Figure 8).

c) Colors Class: at least 90% of the grains classified under the Colors Class, with up to 10% of other cultivars from the Colors Class showing some contrast in color or size:

c.1. Smooth Brown Subclass: cultivars presenting brown, smooth tegument grains, having tone ranging from light to dark and a wide range of sizes and shapes (Figure 9).

c.2. Rough Brown Subclass: cultivars presenting brown, rugous tegument grains, having tone ranging from light to dark and a wide range of sizes and shapes (Figure 10).

c.3. Crowder Subclass: cultivars having smooth, light-brown tegument grains, relatively large and thick, slightly compressed at the edges, having approximately equal width, length and height (Figure 11).

c.4. Evergreen Subclass: cultivars having smooth, slightly greenish tegument grains (Figure 12).

c.5. Green Subclass: cultivars having green tegument and/or cotyledons (Figure 13);

c.6. Cream Subclass: cultivars having smooth, creamy-yellow tegument grains (Figure 14).

c.7. Vinegar Subclass: cultivars having smooth, red tegument grains (Figure 15).

c.8. Blue Goose Subclass: cultivars having smooth, bluish tegument grains (Figure 16).

c.9. Mottled Subclass: cultivars having smooth, gray-mottled or bluish grains (Figure 17).

c.10. Brown-striped Subclass: materials having brown-tegument grains, with longitudinal darker brown stripes (Figure 18).

d) Mixed-color: product having grains of different classes and failing to fit in the specifications described in the previous classes.

Figure 2. Class White, Subclass Smooth White.

Figure 3. Class White, Subclass Rough White.

Figure 4. Class White, Subclass Black-eyed pea.

Figure 5. Class White, Subclass Brown-eyed.

Figure 6. Class White, Subclass Red-eyed.

Figure 7. Class Black, with opaque tegument.

Figure 8. Class Black, with bright tegument.

Figure 9. Class Colors, Subclass Smooth Brown tegument.

Figure 10. Class Colors, Subclass Rough Brown.

Figure 11. Class Colors, Subclass Crowder.

Figure 12. Class Colors, Subclass Evergreen.

Figure 13. Class Colors, Subclass Green.

Figure 14. Class Colors, Subclass Cream.

Figure 15. Class Colors, Subclass Vinegar.

Figure 16. Class Colors, Subclass Blue Goose.

Figure 17. Class Colors, Subclass Mottled.

Figure 18. Class Colors, Subclass Brown-striped.

Besides color and texture of the tegument, hilum traits contribute to compose the visual appearance of the grain; thus, they are also important business features (Figure 19). In some countries, hilum traits may influence the price of the product (COULIBALY; LOWENBERG-DEBOER, 2002).

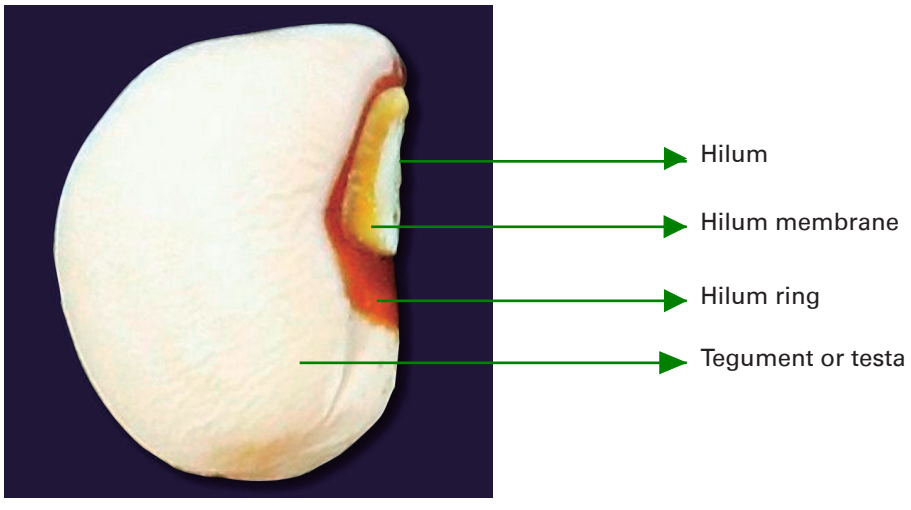

Figure 19. Grain showing the hilum (white part), the hilum membrane (light cream) and the hilum ring (brown).

In Brazil, hilum traits – like size of the hilum, color of the hilum membrane, color and size of the hilum ring and the color and size of the halo – are more important in the White class, especially in subclass Rough White. There is a preference for grains without halo, grains with small hilum, small hilum ring with hilum membrane and grains with light brown hilum ring. Among these traits, the color of the hilum ring is the most important for commerce. Figure 20 shows a sample of color variation that occurs in the hilum ring among cultivars. It is important to say that, with seed aging, light-colored hilum ring tends to become darker, ranging from dark brown to almost black.

Cultivars with grains with small hilum and hilum ring are common in the subclasses Smooth White and Butter. However, this characteristic is very rare in the subclass Rough White, making its obtaining an objective for the cowpea breeding program (Figure 21).

The size of the hilum ring does not appear to be important in subclasses White which present halo. However, the size and the color of the halo have great commercial importance. There are three main subclasses of the halo: black, red and brown. The preference is for seeds that present medium size halo, with defined contours and black color – black-eyed, which in Brazil is called *fradinho*. Figure 22 presents White class grains with the characteristics of hilum and halo with the greatest commercial acceptance.

In Brazil, cowpea landraces and improved cultivars present two types of seed tegument texture, smooth and rough. Nevertheless, the rough tegument is found only in White class, which usually has a differentiated price, being preferred in some local markets. Rough brown tegument is not found among Brazilian landraces, but only in introduced genotypes (Figure 23).

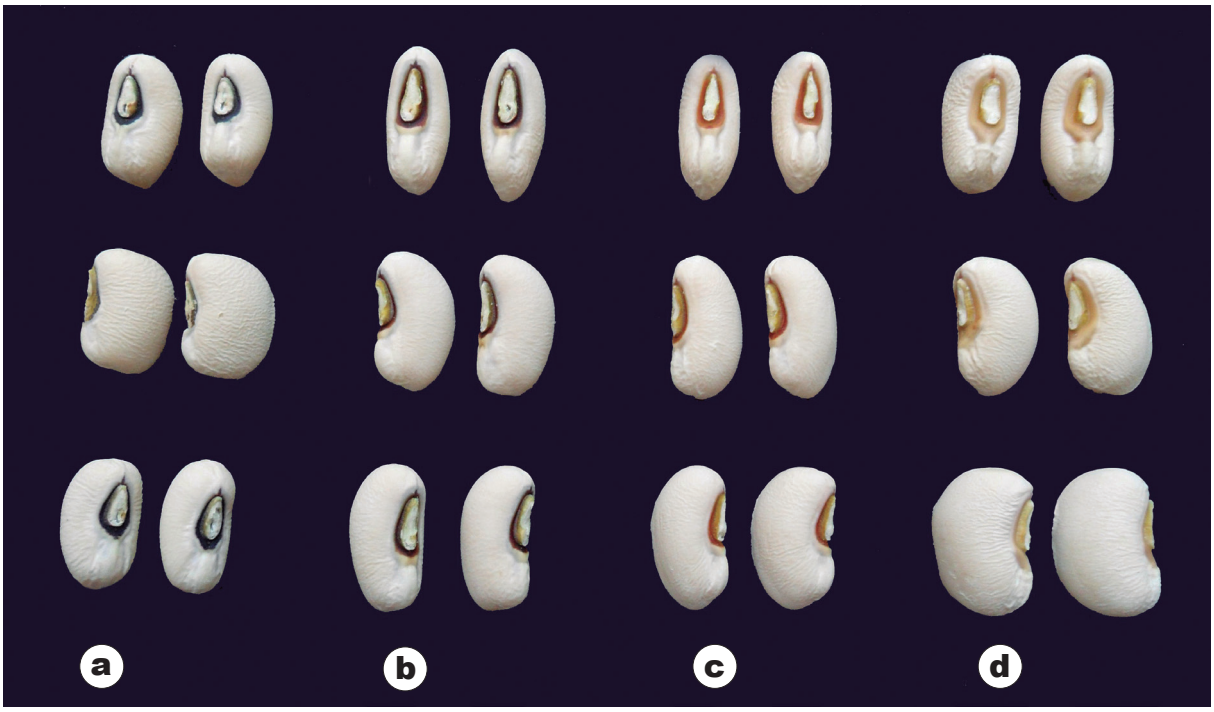

Figure 20. Grains with different colors for the hilum ring: (a) grains with black hilum ring. (b) grains with dark brown hilum ring; (c) grains with brown hilum ring; (d) grains with light brown hilum ring;

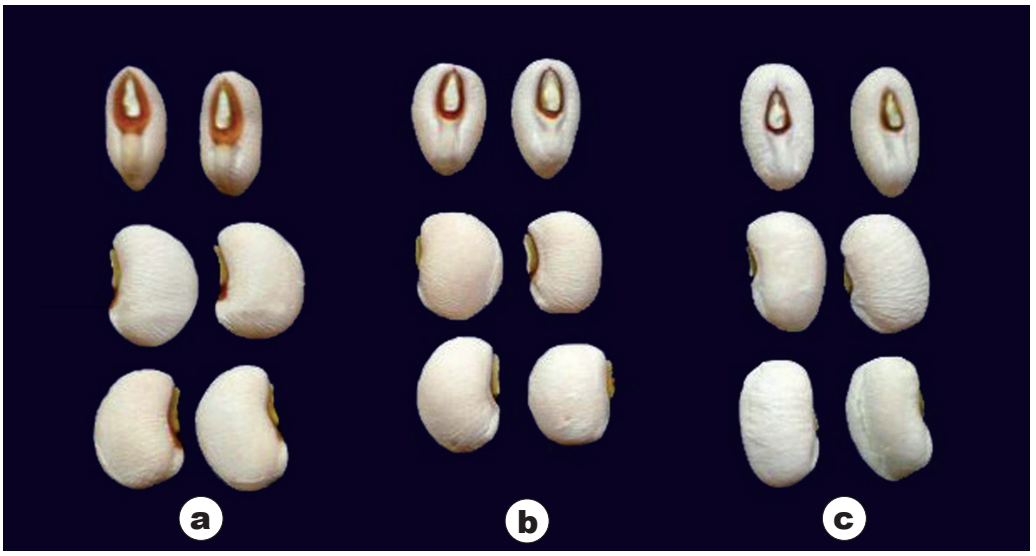

Figure 21. Grains with different types of hilum and hilum rings: (a) grain with big hilum and big hilum ring and without halo; (b) grain with medium size hilum, medium size hilum ring and without halo; (c) grain with small hilum, small hilum small ring and without halo.

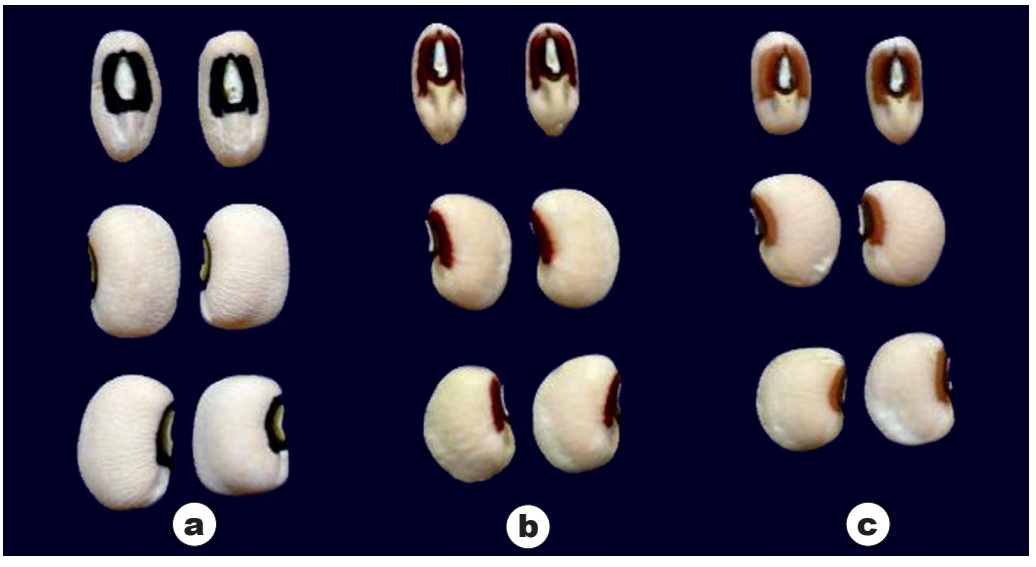

Figure 22. Grains with different types of halo: (a) grains with black halo (black-eyed); (b) grains with red halo (red-eyed); (c) grains with brown halo (brown-eyed).

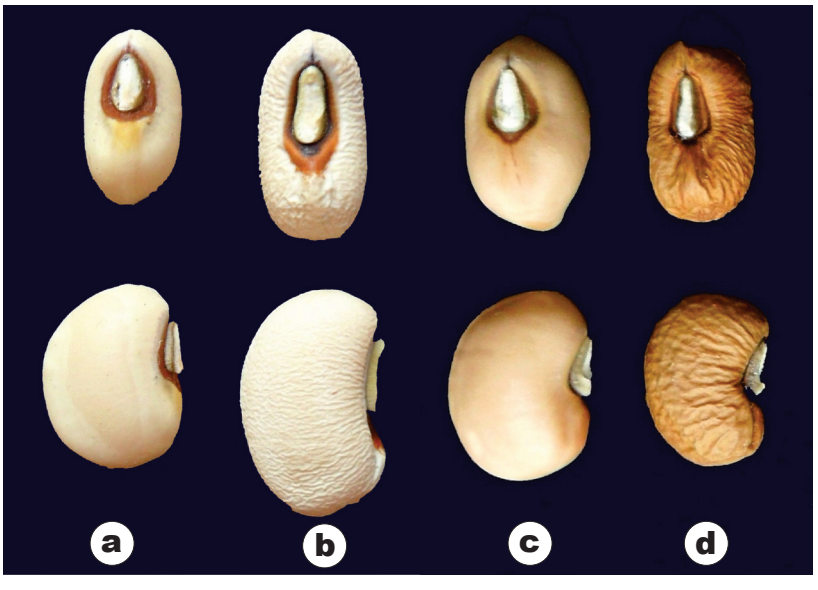

Figure 23. Grains showing types of teguments: (a) white and smooth; (b) white and rough; (c) brown and smooth; (d) brown and rough.

Singh and Ishiyaku (2000) reported that seed tegument texture is an important trait in determining the acceptability of cowpea varieties and that seed with rough tegument is preferred in Western and Central Africa, since this type of seed permits easy removal of the tegument and this removal is essential for traditional food preparations. They also reported that smooth seed tegument is preferred in Eastern and Southern Africa, as well as in parts of South America, where cowpea is consumed as boiled beans, without removing the seed tegument.

As regards the shape of grains, Krutman et al. (1968) have characterized them in five formats: kidneyform, ovoid, globular, rhomboid and irregular. However, cowpea has a larger variety of shapes, and some of them are predominant in local and improved cultivars. Figure 24 shows the main shapes found in the market. Bulk trade presents all these shapes, with predominance of the kidneyform, rhomboid, oval, rectangular and crowded (Canapu). In packaged trade, predominant shapes are kidneyform, oval, rhomboid and rectangular, all of them without marked edges.

Grain size is also a very important character, for both internal and – mainly – external market. In the domestic market, depending on the grain type, there is a specific preference for size. It is important to say that for cowpea, like in other grain crops, grain size is evaluated based on the weight of 100 grains. In Brazil, only for the Butter subclass, the preference is for grain weighing less than 10 g per 100 grains. Moreover, for the subclasses Rough White and Fradinho (Black-eyed), the preference is for grains with a weight exceeding 25 g per 100 grains. In general, the major part of cowpea landraces and improved cultivars have weight of 100 grains ranging from 15 g to 25 g, with higher concentration between 15 g and 20 g. Brazilian exporting companies require that 100 g has a maximum of 400 grains, in other words, 25 g per 100 grains; however, depending on the importing country, there is a certain tolerance: some exportations have been made with 500 grains per 100 g (FREIRE FILHO et al., 2011). Ehlers and Hall (1997) said that in many areas consumers prefer grains with 100 grain weight exceeding 18 g. Langyintuo et al. (2003) presented data of mean weights of 100 grains in different countries: 16 g in Cameroon, 12.2 g in Ghana, 18.6 g in Nigeria, 18 g in Senegal, 11.6 g in Mali, and 16.4 g in Niger. Similar data are presented by Faye et al. (2004), to Senegalese markets, Langyintuo et al. (2004), to Cameroonian and Ghanaian markets, and for Mishili et al. (2009), for Southern Ghanaian, Malian and Nigerian markets. In all these studies, the authors emphasize the preference of the markets for large grains, information that is enforced by Coulibaly et al. (2010). But what may be called "large grain" in cowpea? Omoigui et al. (2006) present some weights of 100 cowpea grains, and it can be deduced that they were classified as the following: small (less than 15 g), medium (from 15.1 g to 20 g), and large (greater than 20 g). The same classification was organized by Manggoel (2011). Freire Filho et al. (2011) present the following classification: extra-small (less than 10 g), small (from10 g to 15 g), medium (from 15.1 g to 20 g), large (from 20.1 g to 25 g) and extra-large (greater than 25 g). It is possible to verify that there is a concordance among the scales of grain size presented until 20 g. However, the scales give no emphasis on large grains weighing more than 30 g per 100 grains, condition that usually reaches better market prices. Based on this, the following scale is presented:

Extra-small	- weight of 100 grains <= 10 g.
Small	- weight of 100 grains from 10.1 g to 15 g.
Medium	- weight of 100 grains from 15.1 g to 25 g.
Medium-small	- weight of 100 grains from 15.1 g to 20 g.
Medium-large	- weight of 100 grains from 20.1 g to 25 g.
Large	- weight of 100 grains from 25.1 g to 30 g.
Extra-large	- weight of 100 grains > 30 g.

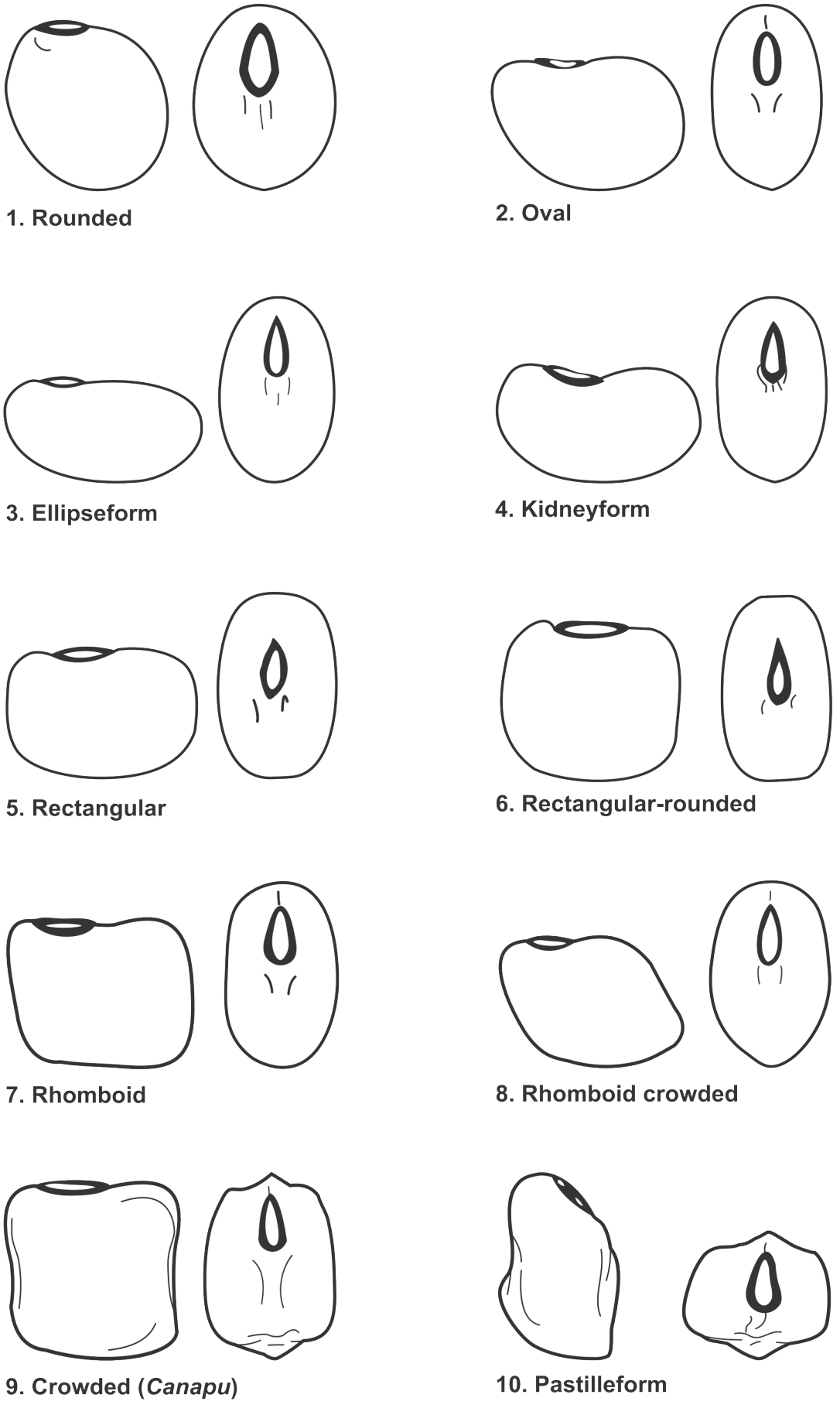

Figure 24. Main formats of cowpea grains found in Brazilian commercial cultivars.

With regard to commercial classes, considering that there are regional preferences or even localized preferences in small markets, all classes and subclasses of grains may be found. However, the predominant subclasses are Smooth Brown (Mulato), Smooth White, Rough White, Crowded (Canapu) and Evergreen. In the trade of packaged grain, the predominant subclasses are Smooth Brown (Mulato), Evergreen and Smooth White, Rough White and Black-eyed (Fradinho). This last subclass is usually sold in packages of 500 g, has a differentiated price and is distributed by large supermarket chains. This type of grain is used to prepare acarajé (ball made of cowpea flour fried in palm oil), and is also consumed in typical Southeastern Brazilian dishes. According to Ehlers and Hall (1997), this is the most suitable variety of grain for exportation.

In Brazil, the product cowpea, for marketing purposes, can be considered well regulated and classified. Thus, it is essential that researchers, technicians, producers, traders, industrialists and distributors learn about the regulation and classification of this product. Only with this knowledge a well-characterized product with established quality standards can be put on market, able to meet demands of all components of the commercial chain and, in special, the demands of consumers.

Market

Brazilian Market

Three well-established market segments have been identified for cowpea, namely: dried beans, fresh beans (fresh pods or threshed fresh grains) and seeds. The market for industrially processed cowpea grains is at an early stage. Regarding the market for dried beans, in the North and Northeast regions, common beans and cowpea do not compete for area of production because the common bean is not well adapted to the climatic conditions of these regions. However, common bean brought from other regions competes for market with cowpea, and, whenever there is a decrease in cowpea supply, the market is supplied by common bean, sometimes imported. There is, in the North and Northeast regions, an estimated permanent shortage of cowpea: 17,577 tons and 102,281 tons, respectively. In the Midwest, however, where cowpea crops are still expanding, there is a surplus of 38,272 tons (Table 4). In the North and Northeast regions, as a result of such deficit, common beans, usually from other regions, have gained a larger market share.

Table 4. Estimate of supply and demand for cowpea in the North, Northeast and Midwest of Brazil based on the average for the period 2005 to 2009.

Region	Population (inhabitant)[1]	Estimated population consumer of cowpea[2]	Consumption *per capita* (kg/person/year)[3]	Estimated demand (t)	Production (t)	Surplus/ Deficit (t)
North	15,359,608	4,607,882	13.65	62,898	45,320	-17,577
Norteast	53,591,197	26,392,832	20.03	528,648	426,367	-102,281
Midwest	5,362,190	268,110	13.65	3,659	41,931	38,272
Total	**74,312,995**	**31,268,824**	**33.68**	**595,205**	**513,619**	**-81,586**

[1]Estimated population in 2009 (IBGE, 2010). [2]Considering that only part of the population consumes cowpea.
[3]Annual per capita consumption of cowpea for each region estimated based on national average of 18,21 kg/person/year (FEIJÃO..., 2009c).

Fresh beans hold a very significant market segment, a high-volume on which very little information is available. Both production and marketing concentrate around urban centers. The fresh beans market is dominated by family farms, because their production requires a lot of manual labor, especially in harvesting and threshing. Both fresh pods and fresh grains are traded in bulk in street markets, whilst packed threshed beans are traded in grocery stores and supermarkets. This commodity has very attractive prices and is an important business option, allowing for potential advances in industrial processing, like canning, cooling and freezing (ANDRADE et al. 2010; KRUTMAN et al. 1971; ROCHA, 2009).

The seed market segment is also very promising. In the North region, there is an estimated potential demand of 1,364 tons; in the Northeast region, there is a 32,241 tons demand; and in the Midwest region, 4,955 tons (Table 5). However, certified seed use is less than expected, except in the Midwest region, where certified seed is utilized in most of the cropping area. In the North and Northeast regions, certified seed use accounts for estimated 10%.

A summary cowpea market-production chain is provided on Figure 25. It suggests that growers are still the predominant source of seed, especially in the case of family farmers. In relation to the dried cowpea, the production is partly channeled to own consumption, and the remaining is sold to middlemen, who pass it on to merchants, grocers and packers, who further pass it on to distributors or directly to consumers. However, some major growers trade their production directly to packers and distributors and to exporters.

It is relevant to say that the preference for a particular variety of cowpea grain will vary from country to country and, within the same country, from region to region. In order to sell their production to new markets in the country and abroad growers have to be aware of: who is willing to buy their commodities? What variety of grain is the buyer willing to buy? What are the buyer's product quality requirements? How much is the buyer willing to buy? How often? At what price? And, if a foreign buyer, what are the legal and technical requirements in the importing country? Coulibaly and Lowenberg-DeBoer (2002) call attention to the fact that knowing consumers' preference is essential for developing new markets, and breeders should know what characteristics are desired by the consumer.

Table 5. Estimated demand of cowpea seeds to the 1st and 2nd seasons in North, Northeast and Midwest regions(1).

Region	1st season		2nd season		Total
	Area to be planted (ha)	Necessity of seed (t)	Area to be planted (ha)	Necessity of seed (t)	necessity of seed (t)
North	6,084	152	48,481	1,212	1,364
Norteast	1,191,544	29,789	98,103	2,453	32,241
Midwest			123,873	4,959	4,955
Total	**1,197,628**	**29,941**	**270,457**	**8,620**	**38,560**

(1) Data estimated based on average area harvested in the period 2005 to 2009 LEVANTAMENTO..., 2005, 2006, 2007, 2008, 2009) using 25 kg/ha of seed in the North and Northeast, and 40 kg/ha in the Midwest region.

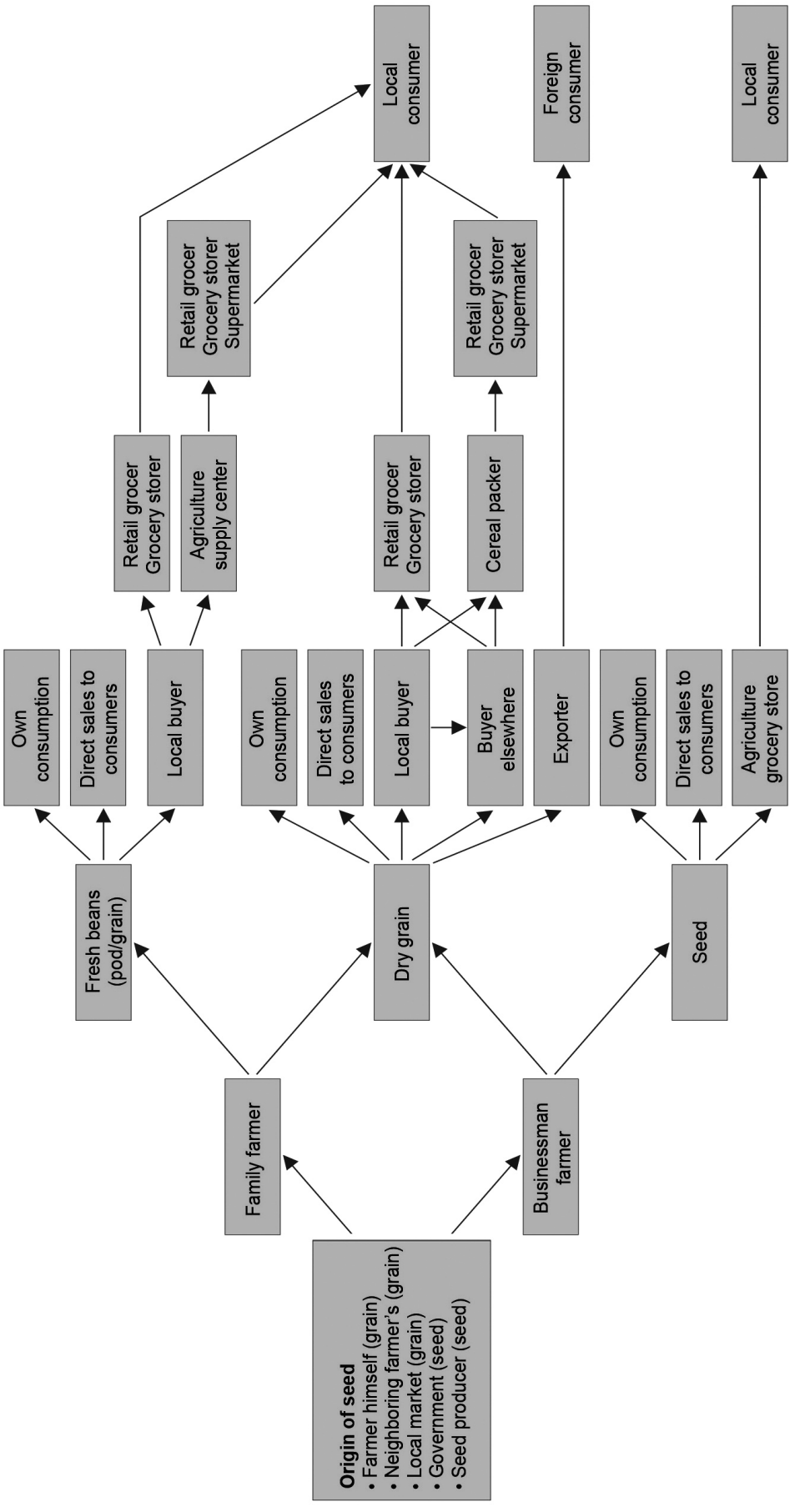

Figure 25. Simplified cowpea market-production chain.

International Market

Cohen et al. (1991) reported that cowpea is present in over 100 countries. The Table 6 shows a list of 97 countries mentioned in the literature that in small or in large scale produce cowpea. However, the Food and Agricultural Organization (FAO) (FAOSTAT, 2011) provides an estimate of production in only 35 countries, and does not include Brazil, the third biggest producer. Table 7 shows estimated cropped area, production and yield by continents and by countries, respectively, over the period from 2005 to 2009, based on FAO data (FAOSTAT, 2011).

According to data described in Table 7, 86.75% of cropped area and 86.5% of cowpea production are in Africa. America accounts for 11.85% and 10.39% of the total area and production, respectively. Although Asia and Europe contribute with small percentages, they have the highest yield. Nigeria and Niger are the biggest worldwide producers; Brazil is the biggest producer in America and the world's third biggest producer, whilst Myanmar has Asia's biggest crop. Considering the cropping area, the volume of production, and in view of the scarcity of food in the world, it becomes clear that cowpea has an excellent potential on the international market. However, the market for this commodity is still mostly restricted to producing countries or to regions of producing countries. It is to be highlighted that there is a relatively well organized formal trade of cowpea among the countries of Central and West Africa, within the Nigerian Cowpea Grainshed (NGG) (LANGYINTUO, 2009; LANGYINTUO et al., 2003; LANGYINTUO; LOWENBERG-DEBOER, 2006;). Langyintuo (2009) reports that NGG accounts for 90% of cowpea traded in the region, along with member countries of Economic Community of West African States (ECOWAS), West African Economic and Monetary Union (WEMU) and Central African Economic and Monetary Cooperation (CAEMEC). An estimated 3.6 million tonnes of cowpea valued at US$ 1.9 billion are produced and consumed within NGG, with Nigeria being the largest producer and importer. It is over than 80% of the cowpea production traded in the world.

It is also relevant to highlight that some countries, including Brazil, are already exporting cowpea (Table 8), providing an important market opportunity (Table 9). In Africa, a traditional market, there is a clear preference for large grains (EHLERS; HALL, 1997, FAYE et al., 2004; LANGYINTUO et al., 2004; MISHILI et al., 2009). Singh and Ishiyaku (2000) report that the rough seed tegument is preferred in Western and Central Africa, while smooth seed tegument is better accepted in Eastern and Southern Africa. Mishili et al. (2009) report that the markets of Nigeria, Ghana and Mali prefer large grains, with preference for colors and types of seed tegument and hilum ring varying from market to market. In North American and European markets, the preference is for large white grain with rough tegument and with a black pigmented area around the hilum, commonly called black eye. Meanwhile, there is no information available about the grain preferences of the Asian market. Therefore, it would be relevant to gather information about the types of grains that are preferred in this market, especially about India and China, two great potential importers. It is worth drawing attention to the fact that much care should be given to new customer preferences regarding the types of grains, the quality of the product and the legal and technical requirements of the importing countries. Such information is essential for gaining and consolidating new markets, especially abroad.

Table 6. Countries that in small or large scale produce cowpea (*Vigna unguiculata* (L.) Walp.).

Continent	Country
America	
North	United States of America[1,7,9,13,19], Mexico[2,6]
Center and Caribe	Guatemala[2,3,17], El Salvador[1,2], Nicaragua[1,2,3], Honduras[1], Panama[2], Costa Rica [1,3], Jamaica[2,3,19], Puerto Rico[2,18], Haiti[2,13,19], Dominican Republic[1,2,18], Trinidad and Tobago[2,5,19], Cuba[7,15].
South	Brazil[1,3,5,6], Guyana[1,2,3,5,8,19], Suriname[1,2,3,5,8], Colombia[1,2,8], Ecuador[5,17], Venezuela[1,3,5,18], Peru[1,5,17,19], Bolivia[8,18], Paraguay[1, 18], Uruguay[1], Argentina[1].
Africa	
West, Center and South	Nigeria[1,3,8,9,10,11,12,15,19], Niger[1,9,10,11,12,13,19], Mali[1,10,11,12,15,19], Sudan[9,10,19], Chad[10,11,15], Burkina Faso[3,10,11,12,15,19], Senegal[1,9,11,12,14,15,19], Guinea[8,18], Guinea-Bissau [19], Liberia [1,3,8], Côte d'Ivoire[10,15], Ghana[3,8,11,12,14,15], Togo[3,10,11,15], Benin[1,3,8,10,11,15],Cameroon[1,3,10,11,15,19], South Africa[1,13,19].
East and Southeast	Tanzania[1,3,8,9,10,19], Uganda[1,8,10,19], Somalia[3,10], Kenya[1,9,10,19], Mozambique[8,9,10], Zimbabwe[1,3,8,10], Zambia[1,3,10], Botswana[1,3,4,8,10], Rwanda[1,10], Burundi[1,10], Malawi[19], Swaziland[3,8,19], Madagascar[19].
North and Northeast	Mauritania[1,15,19], Morroco[16], Algeria[1], Egypt[19].
Asia	
	India[1,3,4,10,17], Sri Lanka[1,3,4,8,10,19], Bengladesh[10], Saudi Arabia[1], Iran[1], Iraq[19], South Yemen[3], Pakistan[1,3,4,10], Afghanistan[1], Lebanon Republic[1], Israel [1], Palestinian State[19], Cyprus[19], China[1,10], Nepal[4,8,10], South Korea[3,4,10], Thailand[8,10,12], Miyanmar (Burma)[1,3,10,19], Vietnam[10], Laos[1,10], Cambodia[10], Philippines[4,8,10,19], Indonesia[1,4,10].
Europe	
	Portugal[1], Turkey[1,10], Greece[10], Italy[1,9,10], Bulgaria[10], Spain[1,10], Serbia[19], Croatia[19], Macedonia Republic[19], Bosnia and Herzegovina[19], Hungary[1,19].
Oceania	Australia[1,10], Fiji Islands[3].

[1] International...(1974). [2]Woolley (1980). [3]Singh (1984). [4]Mishra et al. (1985). [5]Watt et al. (1985). [6]Teixeira et al. (1988). [7]Fery (1990). [8]Singh & Sharma (1996). [9]Ehlers and Hall (1997). [10]Martimore et al. (1997). [11]Singh et al. (1997). [12]Coulibaly and Lowenberg-DeBoer (2002). [13]Singh et al. (2002). [14]Cisse and Hall (2003). [15]Langyintuo et al. (2003). [16]Wetzel et al. (2005). [17]Nene (2006). [18]PERÚ (2010). [19]FAOSTAT (2011).

Table 7. Estimates of cultivated area average, production and yield of cowpea in the world from 2005 to 2009.

Continent/Region/State	Cultivated area (ha)		Production (t)		Yield (kg/ha)	
	Average of period	Average (%)	Average of period	Average (%)	Average of period	Average (%)
Africa						
West, Center and South						
Nigeria	3,970,116	32.492	2,788,116	49.419	702.28	152.09
Níger	4,586,720	37.538	1,084,400	19.221	236.42	51.20
Burkina Faso	748,535	6.126	351,812	6.236	469.99	101.79
Cameroon	105,391	0.862	116,781	2.070	1,108.07	239.98
Senegal	214,416	1.755	83,734	1.484	390.52	84.58
Mali	262,348	2.147	82,869	1.469	315.87	68.41
Democratic Republic of the Congo	108,489	0.888	53,504	0.948	493.17	106.81
Sudan	113,306	0.927	28,600	0.507	252.41	54.67
South Africa	8,945	0.073	5,218	0.092	583.37	126.34
Guinea-Bissau	1,946	0.016	518,333	0.009	266.33	57.68
Subtotal	**10,120,213**	**82.83**	**4,595,344**	**81.45**	**454.08**	**98.34**
East and Southeast						
Kenia	127,449	1.043	63,071	1.118	494.87	107.18
Uganda	73,000	0.597	76,000	1.347	1,041.10	225.48
Malawi	97,289	0.796	57,979	1.028	595.95	129.07
Tanzania	148,713	1.217	67,100	1.189	451.21	97.72
Madagascar	4,709	0.039	4,522	0.080	960.12	207.94
Swaziland	1,432	0.012	679	0.012	474.15	102.69
Subtotal	**452,592**	3.704	**269,350**	4.774	595.13	128.89
North and Northwest						
Mauritania	24,353	0.199	9,319	0.165	382.67	82.88
Egito	2,119	0.017	6,083	0.108	2,870.96	621.78
Subtotal	**26,472**	**0.217**	**15,402**	**0.273**	**581.83**	**126.01**
Total Africa	**10,599,278**	**86.746**	**4,880,097**	**86.500**	**460.42**	**99.72**
America						
North and Caribbean						
United States of America	6,370	0.052	8,799	0.156	1,381.38	299.18
Haiti	40,276	0.330	28,141	0.499	698.71	151.32
Jamaica	207	0.002	221	0.004	1,065.64	230.79
Trinidad and Tobago	137	0.001	451	0.008	3,284.26	711.29
Subtotal	**46,991**	**0.335**	**37,612**	**0.667**	**800.42**	**173.35**
South						
Brazil[(2)]	1,381,951	11.310	505,233	8.955	365.59	79.18
Peru	18,965	0.155	24,847	0.440	1,310.14	283.75
Guyana	105	0.001	172	0.003	1,631.88	353.43
Subtotal	**1,401,022**	**11.466**	**530,252**	**9.399**	**378.48**	**81.97**
Total America	**1,448,012**	**11.851**	**567,864**	**10.387**	**392.17**	**84.93**
Asia						
Myanmar (Burma)	150,680	1.233	157,060	2.784	1,042.34	225.75
Iraq	651	0.005	381	0.007	585.92	126.90
Sri Lanka	11,840	0.097	11,516	0.204	972.64	210.65
Philippines	373	0.003	948	0.017	2,537.76	549.62
Cyprus	91	0.001	157	0.003	1,733.48	375.43
Palestinian State	25	2.10^{-3}	81	0.001	3,173.23	687.25
Total Asia	**163,660**	**1.339**	**170,143**	**3.016**	**1,039.61**	**225.16**
Europe						
Serbia	4,149	0.034	17,184	0.310	4,213.97	912.65
Macedonia Republic	2,461	0.020	7,742	0.137	3,145.71	681.29
Bosnia and Herzegovina	1,117	0.009	1,557	0.028	1,394.05	301.92
Croatia	87	0.001	365	0.006	4,205.07	910.72
Hungary	10	1.10^{-3}	9	2.10^{-3}	862.75	186.85
Total Europe	**7,284**	**0.064**	**23,659**	**0.419**	**3,024.06**	**654.94**
Total world	**12,218,774**	**100**	**5,641,762**	**100**	**461.73**	**100**

[(1)] FAOSTAT (2011), except for the data related to Brazil. [(2)] Estimated based on Sistematic Survey of Agricultural Production (LSPA) (LEVANTAMENTO... 2005, 2006, 2007, 2008, 2009).

Table 8. Cowpea-exporting countries.

Continent	Country
America	United States of America[(1)], Peru[(1)], Brazil[(3)]
Africa	Niger[(2)], Mali[(2)], Burkina Faso[(2)], Benin[(2)], Chad[(2)], Republic of Camaroon[(2)]
Asia	Miyanmar[(4)], Thailand[(4)], China[(4)]

[(1)]Ministry of Agriculture of Peru (PERÚ, 2010). [(2)]Langyintuo et al. (2003). [(3)]Moacir Antonio Tomazetti, business farmer, personal communication, June 6th, 2010. [(4)]COWPEA (2012).

Table 9. Cowpea-importing countries.

Continent	Country
America	United States of America[(1)], Canada[(3)]
Europe	Portugal[(1)], Spain[(1)], Greece[(1)], United Kingdom[(1)], Belgium[(1)]
Africa	Algeria[(1)], Egypt[(3)], Nigeria[(2)], Ghana[(2)], Ivory Coast[(2)], Togo[(2)], Gabon[(2)]
Asia	United Arab Emirates[(1)], Israel[(1)], India[(3)], Turkey[(3)]

[(1)]Ministry of Agriculture of Peru (PERÚ, 2010). [(2)]Langyintuo et al. (2003). [(3)]Moacir Antonio Tomazetti, business farmer, personal communication, June 6th, 2010.

Breeding

Background Overview

Cowpea breending started in Brazil in the second half of the sixteenth century, when the first cultivars were introduced and when farmers began choosing which ones seemed to be the most appropriate for cropping and consumption. However, the cowpea breeding in the modern concept probably started in 1925, when Henrique Lôbbe published a paper in which he evaluated 12 cultivars (LOBBE, 1925). So, the history of cowpea breeding in Brazil can be divided in four phases, considering the institutions involved, the degree of interaction among such institutions, and the level of work organization and planning:

Phase 1 – From 1925, taking as mark the work of Lôbbe (1925), to 1963: during this period, works were carried out without any interconnection or continuity of research.

Phase 2 – From 1963, when the Brazilian Bean Committee CBF was set up at the National Agricultural Research Department (DNPEA), to 1973: during this period, and after CBF was set up, DNPEA, through DNPEA regional institutes, namely, Northeast Agricultural Research and Experimentation Institute (IPEANE), North Agricultural Research and Experimentation Institute (IPEAN) e East Agricultural Research and Experimentation Institute (IPEAL), started to play a more participatory role in bringing together all research efforts regarding cowpea breeding.

Phase 3 – From 1973, when Embrapa was established, to 1991: Embrapa took charge of the duties previously assigned to the National Agricultural Research Department (DNPEA). In so doing, Embrapa Decentralized Units took charge of the roles played by the regional institutes. In 1974, the National Research Center for Rice and Beans (CNPAF) was set up in Santo Antônio de Goiás,

and a partnership between Embrapa and the International Institute of Tropical Agriculture (IITA), located in Ibadan, Nigeria, was formalized in 1977 and was effective until 1986 (WATT et al., 1987). A research team was set up under this agreement only for cowpea, and a national research network to deal with cowpea cropping was set up (GUAZZELLI, 1988). Afterwards, the National Bean Research Program was structured, comprising breeding programs for both common bean and cowpea. This program was coordinated by CNPAF (EMBRAPA, 1981).

Phase 4 – From 1991, when the coordination of the National Cowpea Program was assigned to Embrapa Mid-North, to present: Embrapa Mid-North inherited from CNPAF the responsibility to carry on the National Cowpea Breeding Program. As first step, the work was internally restructured. Based on the progress achieved in the previous phase, especially in relation to grain yield and to virus disease resistance, the goal was redesigned to include the improvement of plant architecture, grain quality, and adaptation to cerrado conditions (FREIRE FILHO et al., 2001a, 2001b). Two national meetings were delivered: 4th RENAC and 5th RENAC, respectively in 1996 and 2001 (REUNIÃO..., 1996, 2001); and simultaneously to the 6th RENAC, the First National Cowpea Congress (I CONAC), 2006 (CONGRESSO..., 2006) was delivered. All such events took place in Teresina, Piauí. The Second National Cowpea Congress (CONAC II) was held in 2009 (CONGRESSO..., 2009), in Belém, Pará. Currently, cowpea research network is deployed across the North, Northeast, Midwesta and Southeast, ranging from the states of Roraima to Mato Grosso do Sul and from Pernambuco to Rondônia.

Germplasm

Genetic resources for breeding, development of new cowpea populations, strains and cultivars are available on the nationwide base collection hosted at the National Center for Genetic Resources and Biotechnology (CENARGEN) in Brasília, Federal District, with more than 4,000 entries (WETZEL et al., 2005). The active collection, hosted at Embrapa Mid-North, Teresina, PI, includes approximately 3,500 entries, and on the working collection, comprising the genetic material handled in the breeding program there are 1,765 entries.

Breeding Strategy

Embrapa's Cowpea Breeding Program set as a priority rearranging the research network so as to bring together all research institutions and enter partnerships with universities, private companies, and other institutions with interest in cowpea, in addition to reaching out all grain production centers in the Northeast, North and other regions. The direct target-public for the program now includes family, entrepreneur and micro-entrepreneur producers, buyers, warehousemen, packers, agribusinessmen, distributors, exporters, agribusiness consulting companies and internal and external consumers. On the other hand, the indirect target-public includes funding agencies, technical service providers, business planning companies and research and educational institutions. The cowpea breeding program is developed in representative ecosystems of the agricultural production in the country, such as caatinga, cerrado, caatinga-cerrado transition zone, coastal tablelands, deciduous forests and pre-Amazon and Amazon zones. Among these ecosystems, cerrado regions, in the North, Northeast and in the Midwest regions, have proved to be highly promising as regards cowpea cropping, with excellent prospects for expanding the cropping area and, consequently, production.

Breeding Goals

The market for cowpea was relatively restricted in the country. It used to be cropped by small and medium family farmers by employing mostly manual cropping methods, and production, trade and consumption virtually focused on the North and especially in the Northeast regions. Currently, cowpea is being cropped by business farmers, with fully mechanized farming methods, and is reaching all major grain production centers and all major trade and consumption centers in other regions of the country, mainly in the Midwest and Southeast regions. The expansion of cropping areas after the inclusion of farmers with a new profile, and consumer market have given rise to new demands and it has expanded the goals of genetic breeding of this crop.

Short-term goals

1) Develop semi-prostrate cultivars, with modern architecture, suitable for family farming; 2) develop erect and semi-erect cultivars, with modern architecture, suitable for fully mechanized farming, intended to agricultural business; 3) increase yield, adaptability, and production stability; 4) increase resistance to pests and diseases; 5) increase the resistance to high temperatures and water stress; 6) increase the levels of protein, iron, zinc and dietary fiber content in the grain;7) improve grain's visual and cooking quality; 8) develop cultivars adapted to all regions in the country.

Medium-term goals

1) Increase the symbiotic potential with nitrogen-fixing bacteria; 2) develop compound-inflorescence cultivars; 3) develop cultivars with mini-processing features, such as cooling and freezing, and with industrial processing, such as meal production, precooked products, and canning; 4) develop cultivars with grain varieties presenting new commercial appeals, such as green beans, brown-striped beans, white grains with persistent-colored hilum membrane and hilum ring; 5) develop super early cultivars that are ready to harvest in less than 60 days; 6) reduce the size of the hilum and hilum ring in the grain; 7) develop cultivars with grain shape, color and size to meet the demands of Asian, European and African markets.

Long-term goals

1) Disseminate improved Brazilian cultivars to other countries; 2) set up an international technical cooperation program for developing cultivars with high levels of protein, iron, zinc and dietary fiber.

Breeding methods

Cowpea breeding methods have been mostly classical, the ones applied to autogamous species. The most commonly employed methods include: 1) introduction of germplasm; 2) mass selection in local cultivars; 3) selection of individual plant with progeny test in local cultivars; 4) pedigree method; 5) single seed descent method (BRIM, 1966; FEHR et al., 1987); 6) single pod descent method (FEHR et al., 1987); 7) backcross method.

Breeding results and progress

Since breeding efforts started, in 1925, until 2009, only 71 improved cowpea cultivars were released. Table 10 shows a relation of released cultivars in the last two decades. Table 11 presents some of the agronomic characteristics of these cultivars. Based on the available data for different cultivars, it appears that the cycle average is 72.7 days; pod length average is 18.0 cm; the number of grains per pod average is 13.1 grains; the weight of 100 grains average is 18.8 g. This average weight for every 100 grains shows that – assuming as reference Ehlers' statement (1997) that in most regions consumers will prefer large grains, weighing more than 18 g /100 grains – Brazilian cultivars, at least on average, already meet such requirement. As regards yield in rainy season crop, in the North region, the average was 1,136.9 kg/ha; in the Northeast region, 1,082.6 kg/ha; in the Midwest region, 1265.2 kg/ha; in the Southeast region, 1,781.0 kg/ha – data from one single cultivar.

Figure 26 shows the yield tendency of cowpea cultivars released in the North region. Figure 26a presents the linear regression coefficient of -15.659 kg/ha, expliciting a trend of decreasing yield. Figure 26b, however, considers only the cultivars released by Embrapa network trails, with a coefficient of 12.30 kg/ha, showing that there is a trend of yield growth. Interceptions of graphics on figure 26a and 26b have different values, respectively, 1,246.5 kg/ha and 1,008.69 kg/ha. This difference can be explained because the first cultivars released in the North region were released specifically for there. However, even the smallest value is higher than the yield average of the region, 830.58 kg/ha (Table 2).

Figure 27 presents the linear regression of the yield tendency of cowpea cultivars released in the Northeast region. Figure 27a, considering all cultivars released in the region, brings a linear coefficient of regression of 7.9615 kg/ha, demonstrating a weak tendency of yield increasing. Figure 27b, on the other hand, considers only the cultivars released by Embrapa network trials and, with a linear coefficient of regression of 14.521 kg/ha, shows a better tendency of yield growth. The interceptions of both graphics are very close, respectively 979.14 kg/ha and 936.95 kg/ha, almost three times the yield average of the region, which is of 329.55 kg/ha (Table 2).

Finally, graphic on Figure 28 refers to cultivars released for the Midwest region. Although with an interception of 459.81 kg/ha, lesser than the regional average (960.38 kg/ha) (Table 2), the linear regression coefficient of 161.08 kg/ha shows a strong trend of yield increase. It is important to say that the regression coefficient of the graphics does not represent genetic gain but only the average performance of cultivars released and the increasing trend in yields over the period.

Table 10. Cowpea cultivars released in Brazil in 1991-2010 period.

Cultivar	National register number[1, 2]	Institution	Year of releasing	Breeding method	Reference
EPACE 11	NT	EPACE	1991	Pedigree	Epace (1990)
Pampo [3]	NT	UFC [4]	1994	Pedigree	Ponte e Alves (1994)
EMEPA 1	NT	EMEPA[5]	1994	Pedigree	EMEPA (1994)
BR17 Gurguéia	5232	Embrapa Mid-North	1994	Single seed descent	Freire filho et al. (1994)
Amapá	4387	Embrapa Amapá	1997	Single seed descent	Cavalcante e Freire Filho (1997)
BR18 Pericumã	NT	EMAPA [6]	1998	Pedigree	Soares (1998)
Monteiro	5235	Embrapa Mid-North	1998	Population	Freire Filho et al. (1998)
Patativa	2501	Embrapa Tropical Agroindustry	1999	Pedigree	Listagem ... (2000)
EPACE V96	NT	Embrapa Tropical Agroindustry	1999	Single pod descent	Barreto et al. (1996); Barreto (1999)
BRS Mazagão	10224	Embrapa Amapá	2000	Selection among introduced access	Cavalcante et al. (2000)
BRS Rouxinhol	12107	EBDA[7]	2001	Single pod descent	Alcântara et al., 2001
BRS Paraguaçu	10624	EBDA	2002	Single pod descent	Alcântara et al. (2002)
Poços de Caldas MG [3]	15757	EPAMIG[8]	2003	Selection from introduced cultivar	Vieira (2003)
BRS Guariba	14768	Embrapa Mid-North	2004	Single pod descent	Freire Filho et al. (2006)
BRS Marataoã	14769	Embrapa Mid-North	2004	Single pod descent	Freire Filho et al. (2005b)
BRS Urubuquara	19785	Embrapa Eastern Amazon	2005	Selection of individual plants from land race population with progenie test	Freire Filho et al. (2009a)
BRS Milênio	19786	Embrapa Eastern Amazon	2005	Selection of individual plants from land race population with progenie test	Freire Filho et al. (2009a)
BRS Potiguá	20115	EMPARN[9]	2005	Single pod descent	Brasil..., (2008b)
BRS Novaera	22156	Embrapa Mid-North	2007	Pedigree	Freire Filho et al. (2008a)

To be continued...

Tabela 10. Continuation.

Cultivar	National register number[1, 2]	Institution	Year of releasing	Breeding method	Reference
BRS Pujante	21752	Embrapa Semi-Arid	2007	Pedigree	Santos (2007)
BRS Xiquexique	22997	Embrapa Mid-North[10]	2008	Single pod descent	Freire Filho et al. (2008b)
BRS Cauamé	22890	Embrapa Mid-North[10]	2009	Single pod descent	BRS (2009b); Brasil...(2010)
BRS Tumucumaque	22891	Embrapa Mid-North[10]	2009	Single pod descent	BRS (2009c); Brasil...(2010)
BRS Pajeú	22995	Embrapa Mid-North[10]	2009	Single pod descent	Freire Filho et al. (2009c); Brasil...(2010)
BRS Potengi	22996	Embrapa Mid-North[10]	2009	Single pod descent	Freire Filho et al. (2009d); Brasil...(2010)
BRS Itaim	25893	Embrapa Mid-North[10]	2009	Pedigree	Freire Filho et al. (2009e); Brasil...(2010)
BRS Juruá	25894	Embrapa Mid-North[10]	2009	Single pod descent	Freire Filho et al. (2009f); Brasil...(2010)
BRS Aracê	25892	Embrapa Mid-North[10]	2009	Pedigree	Freire Filho et al. (2009g); Brasil...(2010)
BRS Acauã	27088	Embrapa Semi-Arid	2010	Single pod descent	Santos (2011a); Brasil...(2011)
BRS Carijó	27089	Embrapa Semi-Arid	2010	Single pod descent	Santos (2011b); Brasil...(2011)
BRS Tapaihum	27090	Embrapa Semi-Arid	2010	Single pod descent	Santos (2011c); Brasil...(2011)

[1]National Register of Cultivar of Brazilian Ministry of Agriculture, Livestock and Food Supply. [2] NT = Not registered. [3]Without participation of Embrapa's Cowpea Breeding Program in the cultivar's obtention and releasing. [4]UFC = Federal University of the State of Ceará. [5]EMEPA = Agricultural Research Company of the State of Paraíba. [6]EMAPA = Agricultural Research Company of the State of Maranhão. [7]EBDA = Agricultural Research and Development Company of the State of Bahia. [8]EPAMIG = Agricultural Research Company of the State of Minas Gerais. [9]EMPARN = Agricultural Research Company of the State of Rio Grande do Norte. [10]Released with the participation of all cowpea breeding net institutions.

Table 11. Agronomic characteristics of cowpea improved cultivars released from 1991 to 2010.

Cultivar	Comercial Subclass	Plant growth habit	Plant type	Average data				Average yield				
								Rainy season				Dry season
				Cycle (day)	Pod lenght (cm)	Seeds per pod	Weight of 100 grains (g)	North	Northeast	Midwest	Southeast	Northeast (Irrigated)
EPACE 11 Jaguaribe	Evergreen	Indeterminate	Semi-prostrate	68	16	14	15		1,200			
Pampo	Brown-White[1]	Indeterminate	Semi-prostrate	75								
EMEPA 1	Smooth Brown	Indeterminate	Semi-prostrate	74	21	17	18		968			
BR17 Gurguéia	Evergreen	Indeterminate	Semi-prostrate	75	17	15	12		976			1,694
Amapá	Smooth White	Indeterminate	Semi-erect	76		15	16	1,200				
BR18 Percumã	Smooth Brown	Indeterminate	Semi-prostrate	75	17	15	17		1,013			
Monteiro	Wrinkled White	Indeterminate	Prostrate	75	18	10	28		476			2,070
Patativa[2]	Smooth Brown	Indeterminate	Semi-prostrate	70	18	13	19		1,267			
EPAC-V-96	Smooth Brown	Indeterminate	Semi-prostrate	68	16	14	15		1,200			
BRS Mazagão	Smooth White	Determinate	Semi-erect	65	15	12	15	1,271				1,895
BRS Rouxinhol	Evergreen	Indeterminate	Semi-erect	75	19	14	17		892			1,509
BRS Paraguçu	Smooth White	Indeterminate	Semi-prostrate	75	18	14	17		890			1,087
Poços-de-caldas-MG	Black-eyed	Determinate	Erect	100	15	9	20				1,781	
BRS Guariba	Smooth White	Indeterminate	Semi-erect	70	18	12	19		1,489			
BRS Marataoã	Smooth Brown	Indeterminate	Semi-prostrate	75	18	15	15		978			
BRS Urubuquara	Smooth White	Indeterminate	Semi-prostrate	75	16	10	22		1,276			
BRS Milênio	Smooth White	Indeterminate	Prostrate	75	17	10	23		1,399			

To be continued...

Tabela 11. Continuation.

Cultivar	Comercial Subclass	Plant growth habit	Plant type	Average data				Average yield				
								Rainy season				Dry season
				Cycle (day)	Pod lenght (cm)	Seeds per pod	Weight of 100 grains (g)	North	Northeast	Midwest	Southeast	Northeast (Irrigated)
BRS Potiguá	Smooth Brown	Indeterminate	Semi-erect	70	23	15	23		1,294			
BRS Pujante	Smooth Brown	Indeterminate	Semi-prostrate	70	18	9	25		704			1,586
BRS Novaera	Smooth White	Indeterminate	Semi-erect	70	15	10	20	1,073	1,254	1,049		1,611 [3]
BRS Xiquexique	Smooth White	Indeterminate	Semi-erect	75	20	16	16	1,074	1,300	679		1,593 [3]
BRS Cauamé	Smooth White	Indeterminate	Semi-erect	70	17	12	17	1,024	1,060	843		1,769 [3]
BRS Tumucumaque	Smooth White	Indeterminate	Semi-erect	70	21	15	18	1,100	1,095	1,100		1,703 [3]
BRS Potengi	Smooth White	Indeterminate	Semi-erect	75	18	14	20	992	910	1,014		1,766 [3]
BRS Pajeu	Smooth Brown	Indeterminate	Semi-prostrate	75	21	16	21	966	997	979		1,863 [3]
BRS Juruá	Green	Indeterminate	Semi-prostrate	78	20	15	19	940	1,080	1,261		1,151
BRS Aracê	Green	Indeterminate	Semi-prostrate	73	20	15	18	1,159	1,110	1,797		1,192
BRS Itaim	Black-eyed	Determinate	Erect	65	16	9	23	1,306	1,165	2,665		1,373
BRS Acauã	Crowder	Indeterminate	Semi-prostrate	70[4]			18		1,338			1,407
BRS Carijó	Black-eyed	Indeterminate	Erect	64[4]			19		1,227			1,651
BRS Tapaihum	Black	Indeterminate	Erect	64[4]			19		1,183			1,619
Average				**72.3**	**18.0**	**13.1**	**18.8**	**1,100.4**	**1,101.5**	**1,265.2**	**1,781.0**	**1,506.3**

[1]Not classified. [2]Data obtained in the states of Piauí and Maranhão in 1999-2001 period. [3]Average of yield obtained from large plots irrigated by conventional sprinkler, in Teresina, Piauí, in 2003, 2004 and 2005. [4]Estimated cycle.

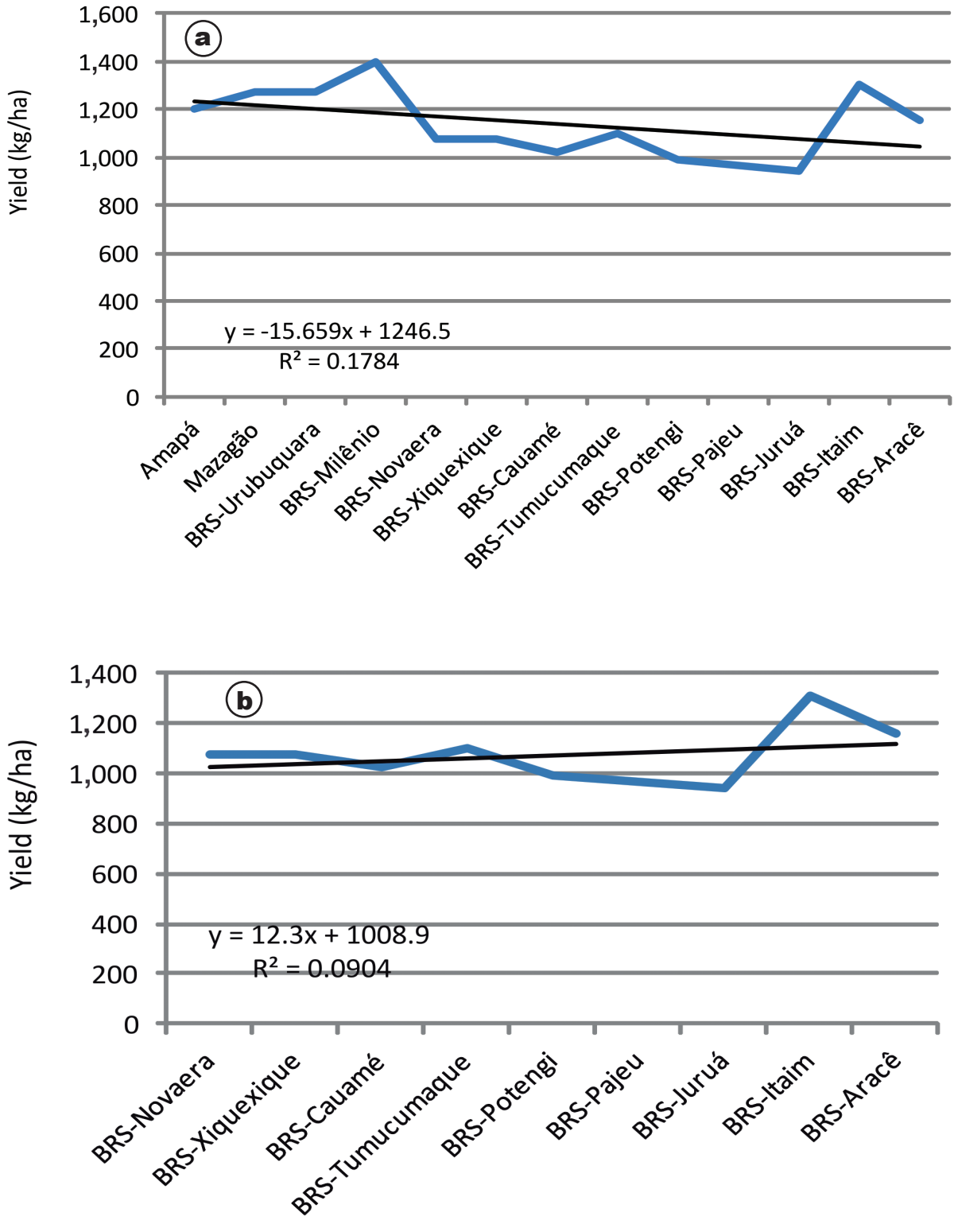

Figure 26. Regression of yield a function of the year of cultivar released for cultivation in the North of Brazil: (a) graphic with all cultivars released, from 1991 to 2010; (b) graphic only with cultivars released based on data of Embrapa trials network, from 1991 to 2010.

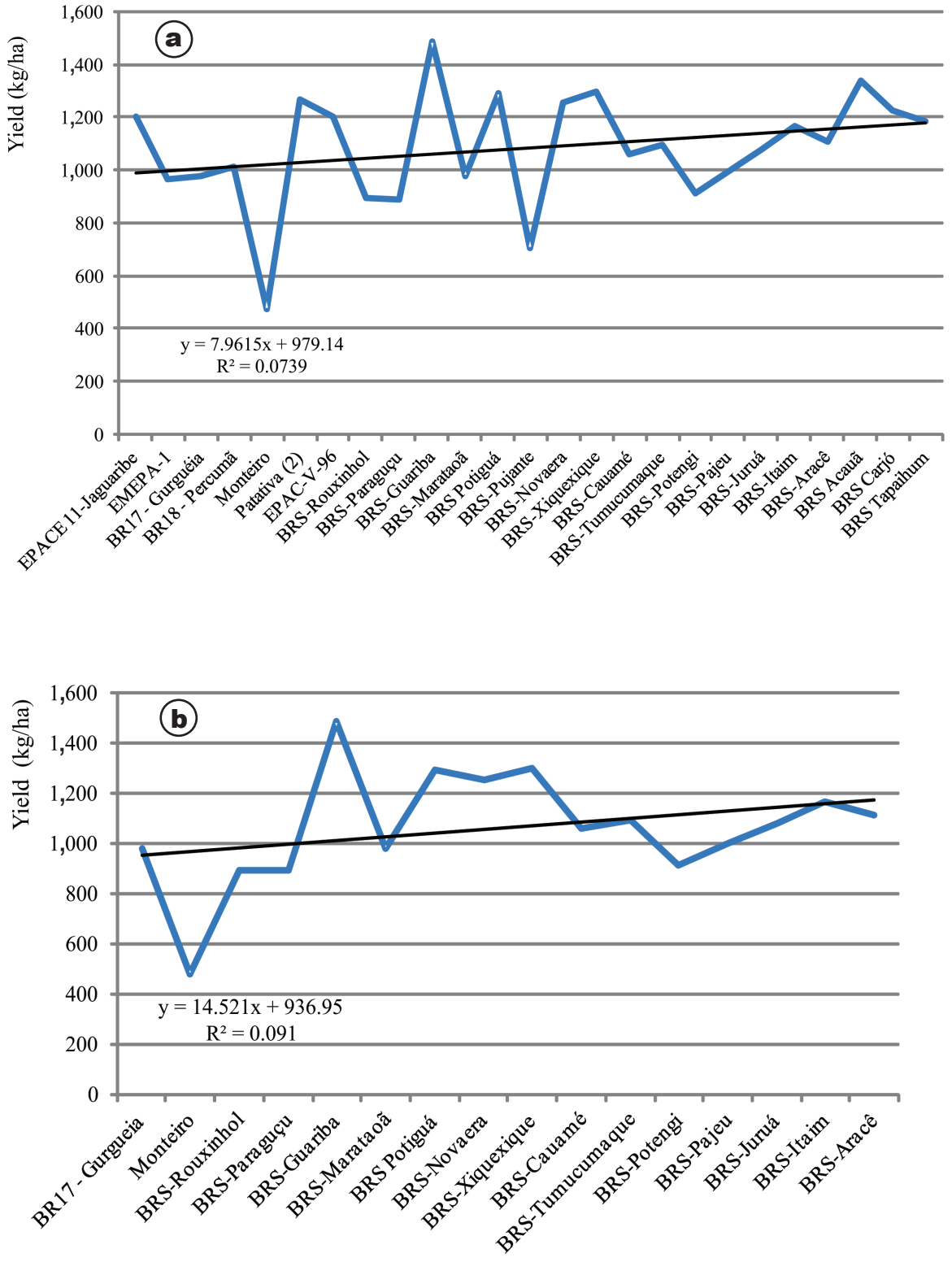

Figure 27. Regression of productivity as a function of the year of cultivar released for cultivation in the Northeast of Brazil: (a) graphic with all cultivars released, from 1991 to 2010; (b) graphic with cultivars released based on data of Embrapa trials network, from 1994 to 2010.

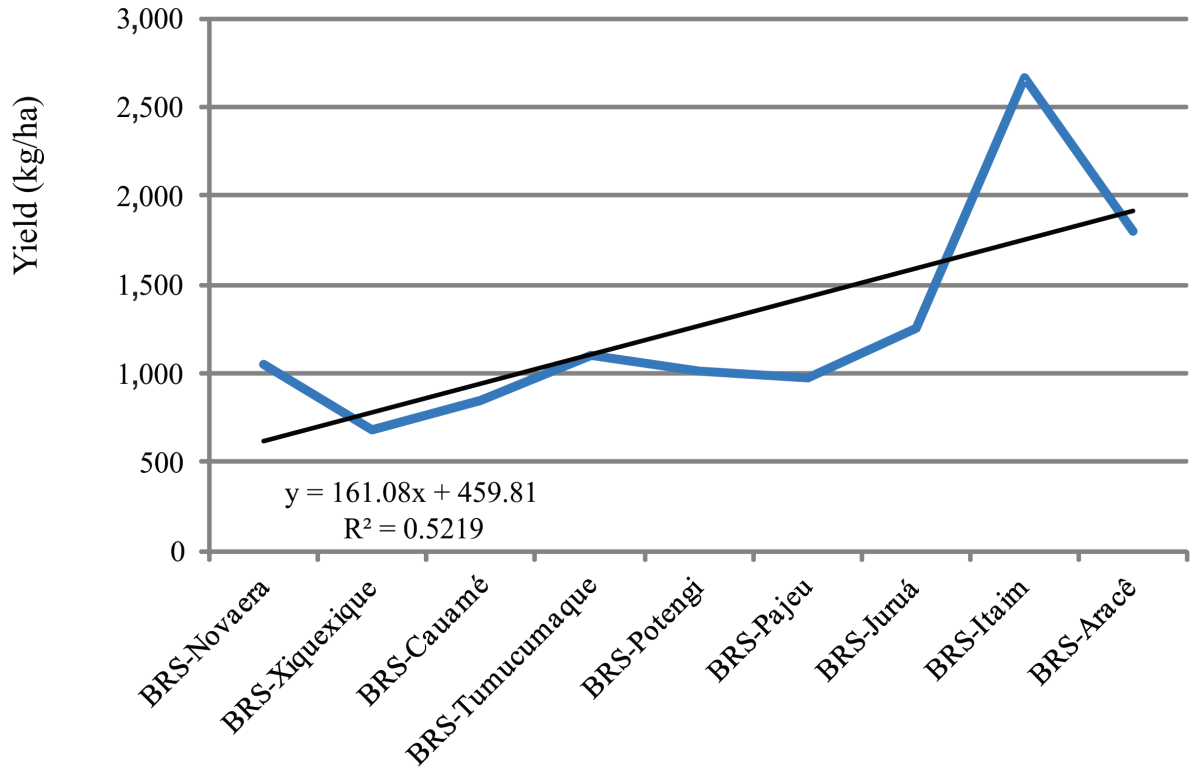

Figure 28. Regression of yield as a function of the year of cultivars released for the Midwest of Brazil, based on data of Embrapa trials network, from 2005 to 2010.

These data can be considered very promising for the present stage of cropping in Brazil, because in the last 20 years the main goal of the program, besides the increase of productivity, was obtaining virus-resistant cultivars with good commercial quality. This fragmentation of priorities reduced intensity of selection for yield. Another important aspect is that most of the evaluation tests were carried out using low to medium-level technology of production. Farmers that are employing high-technology production systems in most cases exceed this average yield. In the Northeast, under conventional irrigation, the average of yield was 1,519.5 kg/ha. These averages of yield and other agronomic characteristics of cowpea in the North, Northeast and Midwest presented in this paper can be used as a referential to the Brazilian cowpea breeding programs.

Table 12 shows some culinary and nutritional characteristics of recently released cowpea cultivars. Such cultivars showed an average protein content of 24.1%; 61.3 mg/kg of iron content; 44,7 mg/kg of zinc content; cooking time of 18'26". Such data are very promising, particularly in the case of iron and zinc content, and show that selection may result in gains for enhanced content of these minerals, which are very important in the nutrition of children, pregnant women and the elderly. It was demonstrated that five cultivars have iron content above 60 mg/kg, and two cultivars have zinc content above 50 mg/kg. BRS Xiquexique and BRS Tumucumaque cultivars stand out with the highest content of both elements. In Brazil, where cowpea production is enough to feed around 28 million people, the release of cultivars rich in iron and zinc represents an immeasurable gain to the health of the population, especially for populations with nutritional defficiency.

Table 12. Nutritional characteristics and cooking time of some cowpea cultivars.

Cultivar	Protein content (%)	Iron content (mg/kg)	Zinc content (mg/kg)	Cooking time[(3)]
BRS Xiquexique[(1)]	23,2	77,4	53,7	22'00"
BRS Tumucumaque[(1)]	23,5	60,6	51,6	13'23"
BRS Cauamé[(1)]	23,9	56,8	46,5	21'07"
BRS Potengi[(1)]	25,4	61,8	35,6	23'24"
BRS Pajeú[(1)]	22,3	57,9	37,7	17'51"
BRS Juruá[(2)]	26,8	65,6	40,9	13'31"
BRS Aracê[(2)]	25,0	61,7	48,6	18'20"
BRS Itaim[(2)]	21,5	48,8	43,4	20'55"
Average	**24,0**	**61,3**	**44,7**	**18'26"**

[(1)]Performed at the Laboratory of Grain Quality, at Embrapa Rice and Beans, Santo Antônio de Goiás, Goiás. [(2)]Performed at the Laboratory of Bromatology, at Embrapa Mid-North, Teresina, Piauí state. [3)]Determinated in Matson adapted cooker, after soaking in water at Embrapa Rice and Beans for five hours and at Embrapa Mid-North for two hours.

Prospects and possibilities

The number of improved cowpea cultivars is very small when compared to other annual crops grown in the country. Therefore, because of this little availability, especially considering that many cultivars are no longer cropped, improved cultivars account for a small portion of the cowpea cropping area in Brazil.

Given this reality, expanding breending cowpea network to all regions is a real prospect, particularly the Value for Cultivation and Use (VCU) trial network, so that farmers from all regions in the country may have access to cowpea cultivars available for cropping. There is also the prospect of obtaining grain varieties having wide commercial acceptance in order to facilitate the inter-regional marketing of the commodity. Moreover, the ultimate aim includes the development of cultivars with a variety of grains capable to meet the requirements of the importing markets, especially those varieties that are little cropped or not cropped at all in Brazil. In order to materialize this prospect, it is expected that molecular tools that can be added to the classical methods in cowpea breeding will be available.

Among epigeal germination annual legumes, cowpea is the only one which presents inflorescence; however, research findings show that an increase in yield can be achieved by obtaining compound inflorescence materials. Thus, a gain in crop yield is feasible by introducing this characteristic in commercial cultivars.

In view of the advances in biological nitrogen fixation in cowpea, there is the expectation that this practice will become common in all producing regions, and that, if combined with the use of improved cultivars, will reduce costs and increase yield.

Cowpea is a quick cooking food and has a high content of protein and minerals; besides, there are also cultivars that are rich in iron and zinc. This brings the prospect that cultivars biofortified with minerals will be available within a short period of time and that cultivars will be commercially available throughout the country.

Cowpea cropping has a significant and strategic potential in view of the threat of climate change, severe shortage of food around the world and because it is a staple food in more than 65 countries (SINGH, 2006) due to its high nutritional value, plasticity, ability to adapt to a wide range of environments in tropical and subtropical regions of the world.

Considering Brazil's interests, cowpea has a rather important social and economic value to the country. Furthermore, in view of the large number of consumer countries, cowpea enjoys a great prospect as regards the international market. Based on this perspective, breeding cowpea in Brazil, beyond the demands of the internal market, needs to take into account the preferences of foreign traditional and potential markets in order to give support in exportation.

Cowpea breeding must also pay attention to the threats of the expansion of the crop, obtaining genetic materials resistant to pests and diseases that occur in the country. It should also give attention to important pests and diseases that occur in other countries which may arrive in Brazil at any time.

So, cowpea cropping provides a relevant business opportunity for both farmers and agribusiness in Brazil, with a potential to become a major commodity, once breeding risks are well managed.

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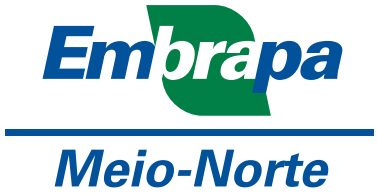

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